10.—THE DONNYBROOK SANDSTONE FORMATION AND ITS ASSOCIATES.

THEIR RELATIONSHIPS AND PLACE IN THE STRATIGRAPHICAL SEQUENCE.

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INTRODUCTION.

During the course of researches into the constitution, structure, organic remains, mineral deposits, and correlation of the geological formations of Western Australia, I have been led to investigate, both in the field and the study, the stratigraphical unit and its associates, which forms the subject matter of the title of this paper.

In the hope that the results of these studies, which relate to the stratigraphical position of this geological unit, may be of use to other scientific workers in somewhat similar investigations, I have been induced to bring them before the members of the society, for as will be inferred from the text, they are of more than mere local interest.

Attention has often been directed to the circumstance that in many geological investigations rocks of any particular formation are noticed long prior to their allocation to any definite system of historical nomenclature, and facts regarding them are recorded without referring the beds to any special stratigraphical horizon.

Although the Donnybrook Sandstone appears to have been unknown as a formation prior to 1912, references were made to it some years previously.

The area over which it extends is however not an entirely unknown region; it is replete with geological facts and also with difficulties.

The literature relating to the Donnybrook Sandstone and its Associates is comparatively voluminous, for no less than forty-eight papers dealing with the matter have already been prepared by several observers and the results published in English, French and German. A list is given in the bibliography.

Despite the fact that since the beds were first examined in the middle of last century no unequivocal determination of their absolute geological age appears to have been arrived at.

HISTORICAL.

In the year 1898 Mr. T. Blatchford prepared a report "Gold Discoveries at Donnybrook," in which brief reference was made to the geological features of the area covered by his investigations. After a second visit, this officer extended his investigations over a wider area, and in a report "On the Development in Mining in the Locality of Donnybrook," published in 1899, noted for the first time the occurrence of an extensive deposit of sandstones, shales and conglomerates, together with coal seams, lying beneath the cover of superficial accumulations. No direct evidence, however, as to the age of the sedimentary series was forthcoming. This report, which was accompanied by a geological sketch map and section showing the known extent of the sedimentary rocks, described the occurrence of gold, of secondary origin, in certain ore bodies by which the unaltered sediments were traversed.

The name Donnybrook Sandstone appears to have been definitely applied to this unit as a formation by Mr. E. C. Saint Smith in 1912, in a report published by the Geological Survey as Bulletin 44, under the title "A Geological Reconnaissance of Portion of the South-West Division of Western Australia," which, *inter alia*, summarised the available data regarding the district. This author described the rocks as consisting of almost horizontally bedded sedimentary rocks associated with shales and coal seams, of the geological age of which no conclusive evidence was adduced though he referred them doubtfully to the Mesozoic (?) Era. Mr. Saint Smith noticed that the beds of Donnybrook bore a striking resemblance in their lithological characters to the strata occurring in association with the coals of Collie, which have been regarded as belonging to the Permo-Carboniferous System.

Mr. H. P. Woodward in 1916 continued the survey of the south-western portion of the State inaugurated by the work of Mr. Saint Smith, and in his report, "Notes on a Portion of the South-West Division" published in the same year, referred to the presence in the area to the east and south of the Collie-Naturaliste Scarp to the eastward of the Dunsborough-Augusta Scarp of a tilted and block-faulted plateau made up of sandstone, shales and coal seams of the Donnybrook Series. Mr. Woodward likewise refers to the discovery of basins of the Collie-Donnybrook Series to the eastward of Donnybrook itself. In the concluding portion of his report the hope was expressed that the field work would be continued during the following season, but Mr. Woodward's death after a very brief illness in the early part of 1917, necessitated this important investigation designed to work out its detailed stratigraphy, so as eventually to furnish a clear narrative of the whole of the geological history of the south-west corner of the State, in its economic bearings being suspended. Though no definite age was assigned to the Collie-Donnybrook Series it is quite clear from Mr. Woodward's references to the Collie Coalfield in an earlier report on "The Coal Resources of Western Australia" published in 1915, that he inclined to the belief that it is "either old

Mesozoic or intermediate between that and the Palaeozic" This falls in with that originally enunciated by him in a report issued in 1891 that the Collie River beds were of an early Mesozoic Age; a conclusion which he reached from a study of the physical aspect of the field and the chemical composition of the coal seams. In his "Notes on the Geology of Western Australia" which appeared in the Geological Magazine during 1894, Mr. H. P. Woodward, however stated:—

"A small patch of the Upper Carboniferous formation has been discovered upon the Collie River, consisting of shales, sandstones and coal seams. It is probably one of a series of small basins lying to the eastward of the range . . ."

It becomes desirable at this stage to give consideration to the diverse views which have been held as to the precise position the formation holds in the geological time scale, involving as they do some yet unsettled points of classification. This question is one about which there has been considerable divergence of opinion, for some authorities have assigned an early Mesozoic and others a Permo-Carboniferous Age to which latter has now with general accord been, on scientific grounds, relegated to the Permian System.

Several weeks in the early part of 1898 were devoted by the author to a geological survey of the Collie Coalfield, during the course of which every locality where any section of the rocks could be seen was visited. Owing to the surface being covered by recent superficial deposits, sections could seldom be seen, and were only noticed along the lines of most rapid erosion, the watercourses. Sufficient evidence was not obtained during the field investigations to enable any statement as to the age of the beds to be made, and no recognisable fossils were found. The results of this survey were published in 1899 and the report included a geological map and sheet of bore sections.

In an address entitled "Recent Advances in the Knowledge of the Geology of Western Australia" delivered by myself to the Section of Geology at the Adelaide meeting of the Australasian Association for the Advancement of Science in 1907, the question of the precise age of the Collie River beds was reviewed in the light of new evidence which had then become available, and involved a necessary rectification of the earlier view. The conclusions drawn from this revision were stated in the following words:—

"In view of all the evidence at present to be deduced from the plant remains and the marine organisms in the beds associated with the Collie coal seams, despite the nature of the coal and the physical characteristics of the basin, I am constrained to admit that a Permo-Carboniferous Age of the Series presents the strongest claims to acceptance."

Mr. E. F. Pittman, the Government Geologist of New South Wales, after a brief visit to the State referred in his report, "Notes on the Geology and Mineral Resources of portions of Western Australia" published in 1898, the Collie River beds to the Mesozoic Period. Mr. Pittman advanced this view after an examination of certain fossil plant remains he collected had been made by Mr. R. Etheridge, junr., Palaeontologist to the New South Wales Geological Survey and the Australian Museum, and determined by him (with hesitation) as the genus *Sagenopteris* one of the typical Mesozoic fern-like forms. Some years later Mr. Etheridge re-examined the doubtful Sagenopteris and in a report, "Plant Remains from the Collie Coalfield" published in 1907, amended his previous determination, and looked upon it as *Glossopteris*, thus re-assigning the age of the beds to the Permo-Carboniferous Period.

In an important report by Dr. R. L. Jack published during 1905 and prepared by him as Royal Commissioner on the Collie Coal Industry under the terms of which he was instructed to include geological considerations, it is stated that the area occupied by the coal measures amounted to about 50 square miles. This author also pointed out that between the coal seams are alternations of shales, sandstones, and grits, the shales being less argillaceous and the sandstones less coherent than is customary among the Carboniferous or Permo-Carboniferous formations of Europe, Africa, and Australia.

The stratigraphical position of the Collie River beds is especially referred to in paragraph 14 of the report in these words:—

"The evidence bearing on the age of the coalfield is at best inconclusive. High authorities have indeed expressed the opinion that it was of Palaeozoic Age—Carboniferous or Permo-Carboniferous—but all these opinions are founded exclusively upon the presence of the fern Glossopteris which is now known to range from Carboniferous up to late Cretaceous. The shales are coarse-grained and incoherent and badly adopted for the preservation of plant remains, and of all the fossils that I have seen I venture to think that few palaeontologists would be bold enough to say more than that they are Glossopteris or something like it. Several observers have informed me from time to time that they have seen fossil plants which, whatever they were, were not Glossopteris, but none have yet succeeded in bringing them, in a recognisable condition under the notice of any palaeontological authority."

A geological map and cross section accompany the report, and upon the map the age of the coal measures has been set down as undetermined. Dr. Jack makes reference to the entire absence of igneous dykes penetrating the coal measures, and concludes from this that the strata were deposited after the cessation of volcanic activity, and therefore at a somewhat later epoch. This deduction was probably drawn from the fact that evidence of igneous activity was present and had been discovered in a bore hole (Diamond Drill Bore No. 5) situated some little distance outside the western edge of the coal measures in Ironstone Gully. This bore, after passing through surface soil, etc., ferruginous sandstone and conglomerate, encountered an olivine-diabase at 91 feet 6 inches from the surface; operations were discontinued at a depth of nearly 97 feet without meeting with the rocks beneath.

Since the publication of the earlier papers the work of Mr. F. Chapman, Palaeontologist to the National Museum, Melbourne, resulted in considerable additions to our knowledge of the fossil fauna and flora of the Collie River beds. This gentleman concluded in an official report, "Notes on Fossils from the Collie Coalfield in the Collection of the National Museum, Melbourne," published in 1907, that an examination of the collection of fossils from the beds between the coal seams at Collie forwarded by the Premier of Western Australia, the plant remains and the associated foraminifera pointed in a general way to a Palaeozoic Age of the strata.

The month of April, 1914, saw the appointment of a second Royal Commission on the Collie Coal Industry under the chairmanship of Dr. W. G. Woolnough, the Professor of Geology in the University of Western Australia. The published report of the Commission, which was accompanied by a geological map of the Collie Coal Basin, states that the main facts regarding the geology of the area, so far as the Commissioners understood them, were:—

(a) the sediments and coal seams forming the Collie Coal Measures probably covered a greater area than their remnants occupy at the present time and were deposited in Permo-Carboniferous time;

(b) they were in all probability continuous with the Donnybrook Sandstones of the south;

(c) the area of the Collie Coal Basin was much greater than had been suspected in 1905 at the time the report of the first Commission was issued;

(d) the dominant structural features were a complicated fault system uninterrupted for many miles and responsible for the approximately rectilinear form of most of the boundaries of the basin;

(e) the occurrence of beautifully preserved leaves of the fern-like plant *Glossopteris* in association with the coal seams.

A considerable difference appears in the outline of the north-eastern boundary of the basin in the 1916 map, and that defined by Dr. Jack in 1905, though the two Commissioners are in close agreement regarding the north-western and south-western limits.

Dr. E. S. Simpson, in a report published during the year 1917, dealt in some detail with "The Chemical and Physical Properties of some of the Donnybrook Sandstones" in which it was briefly stated that the geological age of the sandstones was unknown.

A report of Mr. F. G. Forman on an "Inspection of Gold Prospecting at Donnybrook" issued in 1935 briefly refers to the Donnybrook Sandstone as being of Permo-Carboniferous Age. This author points out that these beds rest upon the ancient crystalline and metamorphic sedimentary rocks. Reference is likewise made to the occurrence of gold in the sandstones associated with fracture zones or joint planes filled with chalcedonic silica, producing a rock resembling quartzite. The gold is stated to be of secondary origin, the parent source being in the older underlying crystalline and allied rocks, which are traversed by quartz reefs, responsible for the yield of 841.76 ounces of gold by crushing 1,653.30 tons of ore.

The organic remains hitherto found in the Donnybrook Sandstone Formation are only few, and the palaeontological data relied upon by most of the observers referred to in considering the geological age of the strata was almost exclusively based upon the occurrence of the fern-like plant *Glossopteris*, which is now known to have a vertical range from the Carboniferous up to the Triassic Period.

The importance of foraminifera as a palaeontological aid to correlation is now generally recognised; of these there have been recorded from the Collie Series, one species of the family Lituolidae, two belonging to Textulariidae, and two of the Rotaliidae. The genus Valvulina from Collie, which ranges from the Palaeozoic Period to the present day, has a large development in Cretaco-Tertiary formations elsewhere but is somewhat rare in Triassic strata, though those which are identifiable appear to have kinship with such as made their first appearance in Palaeozoic times. The presence of the depauperated genera of foraminifera, which have been recorded from some of the sandstones associated with the coal beds of Collie, while of importance in itself does not indicate an absolute identity with strata of undoubted Palaeozoic Age elsewhere.

The analytical examination of the early investigations has been necessary in order to set out the facts in their proper perspective, and in addition to do justice to those who have observed and described so much.

Having in this historical review given a brief *aperçu* of the principal original observations made upon the rocks, and the evidence used in considering their geological age prior to the subdivision given the name it now bears, it is proposed to describe the formation more minutely, not only as regards its distribution, characters, stratigraphical relations to underlying and overlying formation, together with some of its problems and to discuss its correlation, both intercontinental and long distance for this latter represents one, if not the chief scientific objective to which an investigation of the aspects previously enumerated inevitably leads.

DISTRIBUTION OF THE FORMATION.

The country in the vicinity of the township of Donnybrook—situated in the extreme south-west corner of the State, between Geographé Bay and Greenbushes tinfield, on the Bunbury to Bridgetown railway line—is for the most part covered with laterite, and other superficial deposits, which effectually conceal the underlying rocks, except in the gullies and on the hill-slopes.

Lying beneath this ubiquitous cover is a widely spread deposit of almost horizontal rocks, which consist of fine-grained sandstones, alternating with bluish-grey pyritous clay shales (one of which contains a seam of iron pyrites six inches in thickness), coal seams and conglomerates. The basal beds are very arenaceous, and lithologically virtually arkoses. The uniformity of the series in respect to its lithological and other characters, constitutes one of its striking features.

The beds rest upon the ancient crystalline and metamorphic rocks which make up the complex of the Darling Range, as developed in this portion of the South-West Division. Outliers of the series have been met with in several of the hills in the watershed of a north and south tributary of the Preston River, which points to the probability of the contact being of deposition, rather than one of faulting as had previously been suggested.

DESCRIPTION OF THE DONNYBROOK SANDSTONE AND ITS ASSOCIATES.

These sedimentary rocks, which cover a considerable portion of the south-west corner of the State, form a distinct stratigraphical unit, appropriately named The Donnybrook Sandstone from the fact that some of its component beds have been extensively exploited in the neighbourhood of the township of that name. The series is, however, practically confined to the maritime and coastal portions of the South-West Division, and does not appear to have spread over the vast interior of Western Australia.

Mining operations have been carried out in the Donnybrook Sandstone Series within an area lying to the south-west of the township near the head-waters of the Capel River, not far from that powerful fault which forms the southern extension of the Darling Fault Scarp. These operations disclosed the occurrence of impure brown coals of low calorific value, at relatively shallow depths associated with sandstones and shales. Some of these coals, which have an average thickness of about ten inches, at times exhibit traces of lignitic structure. The seams are separated by a similar thickness of sandy and carbonaceous shales.

The series has been penetrated to a depth of 202 feet from the surface in a shaft (Murphy's Shaft) sunk on Prospecting Area 155H, about four miles south of Donnybrook. The shaft exposed the following section:— Gravel and laterite, 8 feet; clay shales, 65 feet; lignite (with shaley bands), 4 feet; sandstone, 10 feet, and loose sandy grit, 12 feet. A bore carried down from the bottom of the shaft passed through 18 feet of sandy shale. The calorific value of six samples taken from the seam of brown coal varied from 5,710 to 6,928 British thermal units.

In addition to the prospecting for coal, quarrying operations have been carried on in the vicinity of Donnybrook on a fine-grained felspathic sandstone, which has been extensively used in many buildings in the metropolis. A number of quarries have been opened during recent years in these gently inclined sandstones at several localities lying within a belt about eight miles in length, which extends from about four miles due north to about four miles south of the Donnybrook Railway Station. The quarries are nearly all situated along the western flanks of the Darling Fault Scarp at a moderate elevation above the general level of the country to the westward at about 200 feet above sea level. The sandstones dip at an angle of about four degrees in a general south-westerly direction.

Geological evidence bearing upon the probable extent, constitution, and structure of the Donnybrook Sandstone Series being incomplete, the Government, during the year 1911, deemed it expedient to have a more or less detailed examination of the area covered by these beds undertaken. The thickness of the formation, as well as the classification of the associated beds, have very many important scientific and economic bearings. The base of the formation has been, but seldom, observed.

The Donnybrook sedimentaries cover a wide extent of country to the westward, where their presence has been proved by the bores put down in the valley of The Vasse River which enters Geographe Bay near Wonnerup some miles to the north of Cape Naturaliste. Bore No. 5 near the eastern bank of the Vasse River, to the south of Busselton, passed through the whole sedimentary series and entered the Pre-Cambrian crystalline rocks at 655 feet below the surface, and bore No. 6 at Newtown reached the floor of crystalline rocks (gneiss) at a depth of 330 feet. These beds were also met with to the northward in No. 2 bore on the Dardanup Estate, in the valley of the Fergusson River. This bore was carried down to a depth of 1,032 feet without the base of the formation having been reached.

What is believed to be the northward extension of these beds has been met with in the experimental borehole put down at Cookernup in the watershed of the Harvey River, about 35 miles to the north of Dardanup. The bore was situated just to the south of the railway station in the township and carried down to a depth of 2,215 feet, through sandstones, grit and shales, without the base of the formation having been unequivocally reached, although from the nature of the core samples it seemed that bedrock could not be very far off. The results obtained from this experimental bore, which was carried out with a Calyx drill, demonstrated the great extent of the formation in a northerly direction from Donnybrook. No organic remains were noticed in the cores submitted, and no coal seams recorded.

The Donnybrook Series extends as far south as Fly Brook, a tributary of the Donnelly River, on the South Coast, about 30 miles east of Cape Leeuwin. The series is made up of beds of sandstone, grit, micaceous clay shale, with seams of coal, which are overlaid by a coarse conglomerate containing large water-worn pebbles of quartzite, quartz and crystalline rocks. A considerable amount of shallow boring has been carried out in this area, the deepest borehole being 128 feet, and in it 17 seams of coal, aggregating 20 feet in thickness, were passed through. The largest seam was five feet four inches thick, with a clay parting of six inches, whilst another seam two feet three inches had a clay parting of two inches. The Fly Brook seams are lustrous black coals with a fracture somewhat resembling jet, though lacking its hardness, whilst a woody structure was clearly visible in the weathered surfaces. The calorific value of a sample of the five feet seam, proved to be 10,167 British thermal units. The coals of Fly Brook bear a resemblance to some of those of the Collie field, of which they may be the southern extension, and possibly the representatives of the uppermost beds of the Collie series. Mr. H. P. Woodward, during the course of an examination of this portion of the State in 1889, devoted special attention to the areas at Fly Brook, which had been taken up as coal mining leases. This observer, in a report published in 1890, stated that though there was not sufficient evidence to determine the exact age of the strata containing the Fly Brook seams, he considered it to be Mesozoic, and noted that the coals appeared to be identical in composition with the cretaceous coals of the Pacific Coast of North America.

A very large development of sedimentary rocks occurs to the eastward of Donnybrook in the neighbourhood of Collie and Wilga, which contains a store of mineral wealth in its coal measures. As a result of the mining operations which have already been carried out, much valuable geological data has been obtained, and which has thrown considerable light upon what may be called the anatomy of the district.

In answer to queries by the Royal Commissioners on the Collie Coal Industry, put to me in 1914, as will be found in that report, it was pointed out that there was no definite proof that the Donnybrook sedimentaries formed part of those occurring at Collie, though there seemed to be sound reasons for believing that such a connection would ultimately be established.

The synchronism of the Collie-Wilga beds with those of Donnybrook is, so far as the facts now go, fairly well established, and implies that they all form part of a single geological formation. The proof of this connection rests almost entirely upon considerations involving an interpretation of the lithological peculiarities of the beds, their architecture, and stratigraphy, in addition to their physiography and diastrophic history.

The Collie-Wilga beds appear as basins resulting from a widespread system of regional block faulting, and had at one time a wider extension.

The beds of the Collie Field lie at an altitude of about 600-700 feet above sea level in a depression near the north-western edge of the tableland of granitic gneiss and allied crystalline rocks, drained by the Collie River and its tributaries. The strata consist of alterations of micaceous shales, cross-bedded sandstones, and grits, with which are three well-defined zones of coal measures amounting to an aggregate of over 140 feet. These latter furnish

the entire coal output of the State, and their importance can be gauged from the fact that they have up to the end of 1938 contributed 13,877,292 tons, valued at £9,142,734.

So far as can be judged from such data as is at present available, the strata have a thickness of more than 2,000 feet.

The boundaries of the coal-bearing beds are almost everywhere defined by faults to the existence of which the basin owes its preservation. The boundary fault on the south-western side of the field has been estimated to have a downthrow to the north-east of at least 2,000 feet. The effect of this block-faulting, and the incoherence of the rocks, has determined the direction of the river in that portion of the valley in which the coalfield lies.

The dip of the strata is, on the whole, fairly uniform, the inclination nowhere exceeding 12 degrees, and is in a general southerly direction.

Despite the fact that the field is traversed by many major faults, the strata have not been subjected to any serious disturbance and have suffered little or no lateral pressure.

Three well-defined productive series of coal measures have been recognised in the Collie field. The lowest certain observers have assigned to the Lower Permian, whilst the middle and uppermost groups have been relegated to the Upper Permian Epoch. The base of the beds in the area has been met with in several localities.

The sandstones of the Collie basin are distinctly crossbedded, and on examination were found to contain garnets, quartz and felspar, minerals in all probability derived from the disintegration of the crystalline and metamorphic rocks upon which they rest and which everywhere surround the field.

The rocks from which fragments of the leaves of plants had been obtained were somewhat bituminous shales, which in all probability resemble forms intermediate between coals and shales. Owing to the conditions of deposition, the coals vary in character, and in places pass insensibly through forms containing earthy matter to carbonaceous shales. The absence of underclay or "seat earth" suggests that the coal seams are in all probability of clastic origin, having been laid down on the floors of lakes or swamps of relatively moderate depth under physical conditions in which differences in climate also played a part. Such conditions would furnish an explanation of the varying percentage of ash in the seams, and also the fact that the coals of Collie possessed properties which differentiated them from others in the Commonwealth.

A somewhat important geological discovery was made during the year 1920 at Collie in a deep bore put down on the Municipal Water Reserve in the township, to a depth of 1,135 feet; this at the time being one of the deepest boreholes in the basin. The borehole passed through alternations of sandstones, shales and 17 seams of coal, one being nine feet six inches thick, and two bands of sandy limestone at depths of 1,083 and 1,133 feet respectively. This discovery of limestone—the first so far encountered—indicates a change from brackish water to estuarine or marine conditions in the Collie basin. This basal limestone, which was penetrated for two feet four inches, without reaching the base of the formation, contained calcite, quartz, felspar, kaolin, ilmenite, rutile, and some organic matter.

The coal-bearing area of Wilga lies on the fairly flat ground between the headquarters of the Preston and Collie Rivers, and is situated about 5½ miles to the north-east of Wilga Siding at about 300 feet above the level of the Collie field.

Though a brief report on Wilga had been made by Mr. T. Blatchford in the year 1918, in which he stated that it was probably a geological replica of the Collie field, the first detailed account of the coalfield, was that given by Mr. R. C. Wilson in 1921. This report placed before geologists a fairly comprehensive statement of the constitution, structure, nature and distribution of the coalseams, and has served as the basis of all subsequent descriptions. The maps and sections showing the relation of the Collie to the Wilga field make it quite clear that the two areas were at one period coterminous and formed part of a more extensive coal-bearing area of identical geological age.

Like its neighbour, Collie, the Wilga field owes its position to having been faulted down into a trough in the ancient crystalline rocks in such a manner as to secure its protection from erosion. The longer axis of the basin, estimated to cover an area of about 24 square miles, is approximately north-west and has a general parallelism with that of the Collie River, and the fault line, which constitutes the south-western boundary of Collie.

Owing to the structural configuration of the area, and the mantle of more recent superficial accumulations, few natural sections are visible, hence an underground survey of the field was inaugurated by means of a scheme of reconnaissance boring.

The greatest depth reached in one of the four deep vertical boreholes was 691 feet, and the shallowest 550 feet 6 inches. The information furnished by these operations added considerably to our knowledge of the constitution and structure of the Wilga field, and supplied data which it was not possible to acquire in any other way. An examination of the material obtained during the course of the boring operations showed that in the lower portions of the north-eastern margin of the basin the beds below the coal-bearing horizon gradually gave place to mudstone, limestone, and boulder conglomerate.

A thin band of impure limestone was met with in No. 1 deep bore at 530 feet, beneath which, at 548 feet, was a conglomerate, assumed to be the base of the coal measures. The component fragments in the conglomerate were granite, ironstone, quartz, quartz diabase, and epidiorite. No trace of any organic remains, whether calcareous algae, glauconite, foraminifera or shells, were found in the conglomerate. Another deep bore (No. 2) carried down to 1,550 feet below the surface, entered a quartz conglomerate at the bottom, made up of pebbles of decomposed greenstone of a similar petrological character to that in No. 1 bore. No. 3 deep bore encountered a conglomerate of granite boulders, 11 feet thick, at 596 feet, resting upon granite, which was penetrated for 12 inches.

The stratigraphical information disclosed by these boring operations showed that the group of Wilga coal seams overlies the marine strata at the base of the series, and that in all probability they are on the same geological horizon as the lowest of the group of coals worked at Collie.

No fossils have, up to the present, been recorded from the Wilga area.

IGNEOUS ACTIVITY.

A striking feature in connection with the geology of the area occupied by the Donnybrook Sandstone Formation is the manifestation of igneous activity, chiefly of a basaltic nature, following or accompanying extensive earth movements.

This vulcanic activity, which has played an important part in the geological history of the south-western portion of the State, appears to have been first referred to by Mr. F. T. Gregory in 1861.

The evidences of this activity have been shown to extend from Bunbury to the south coast, a distance of about 80 miles, having a width stated to be some 12 miles, thus covering an area of not less than 1,000 square miles. This volcanic belt trends in a general north and south direction, parallel to and about six miles to the westward of the Darling Fault Scarp and its southern extension. Owing to the wide area over which these basaltic rocks are scattered, they leave little doubt that the volcanic activity must have been of no small magnitude. These igneous rocks did not, however, succeed in reaching the surface in the more immediate vicinity of the area, near Donnybrook, Collie and Wilga, though there seems to be but little doubt that the igneous magma must have been burrowing about at some distance underground.

No direct evidence as to the geological age of this igneous activity being at present available, such must in the present state of our knowledge be a matter of inference only.

A description of some of the igneous rocks occurring in the Warren River District has been given by Mr. R. A. Farquharson in the Petrological Appendix II. to the report of Mr. H. P. Woodward on "The Reputed Petroliferous Area of the Warren River," issued in 1915.

The prevalent petrographical type of these basic igneous rocks has been exhaustively dealt with by Dr. Edwards in the papers read before the Society and published in two recent numbers of its Journal, and need no further elaboration.

From the point of view of correlation, the chemical and mineralogical composition of this type of basaltic rocks given by Dr. Edwards and hitherto unrecorded in this portion of Western Australia has considerable significance, as will be pointed out later. For precise information as to the age of these volcanic rocks, some reliance has to be paid to the nature of the evidence afforded by a study of those differential subsidences which have affected the south-west portion of the State. The tectonic disturbances resulted, *inter alia*, in the formation of that modified rift valley, of which evidence is available over a wide extent of country between the south coast and that to the northward of the Irwin and Murchison Rivers, and of which the block faulting in the Collie-Wilga area form a part. The extent of this earth movement is graphically depicted on the plan showing the main faults, fault scarps, etc., which forms Fig. 38, of the last edition of the work by Mr. Jutson on "The Physiography (Geomorphology) of Western Australia," published as Bulletin 95 of the Geological Survey.

The correlation of these dislocations can, however, in the present state of knowledge only be arrived at in a very general way. These differential subsidences along the lines parallel to that of the general trend of the

dominant structural features of the district produce in the aggregate very considerable effects. The movements, however, are by no means at an end, and are of such a nature as careful seismological observations carried out over long periods of time alone can detect, The evidences of vulcanicity in association with these lines of fracture are not without their significance and practical interest.

The relationship of the basalt in the neighbourhood of Bunbury, renders it necessary to give its occurrence more than a mere passing notice, as the deductions which directly follow have important scientific and economic bearings. The earliest reference to the basalt at Bunbury would appear to be that in the paper of Mr. F. T. Gregory on "The Geology of a Portion of Western Australia," read before the Geological Society in 1861, and printed in Vol. XVI. of the Quarterly Journal of the Society. This author stated that it was a rudely columnar basalt, and that there was "no rock seen in contact with it;" in addition, the fact was recorded that the basaltic rock appeared about five miles to the south, and after crossing the Capel River outcropped on the south coast eastwards of Flinders Bay.

Mr. H. Lyell Brown, in a report (illustrated by a sketch map and section) printed under the authority of the Legislative Council in 1873, referred briefly to the basalt at Bunbury and pointed out that it was overlaid by limestone and sand. A plan and section of the basalt occurring at Cape Beaufort (Black Head) on the south coast, was also included in the report. Eleven years later (1884), Mr. E. T. Hardman described the basaltic rock at Bunbury as being an eruptive mass, which he could not trace inland. This observer, however, points out in the same report that basalt was found on the north side of the Preston River, resting upon vertical beds of granitic gneiss. The report also states that the basalt, having undergone considerable denudation, it occurred chiefly in patches, spread over an area four miles eastward, half a mile south, and two miles north-west and south-east.

Mr. H. P. Woodward, reporting on his geological investigations carried out in the country between Perth and Bunbury during 1889, that at the latter township "a dyke of columnar basalt outcrops on the beach," a statement implying that the rock had been thrust between the rocks as an intrusive sheet.

The boring operations and other collateral investigations carried out within the Municipality of Bunbury and its environs in connection with the underground water supply, have shown quite clearly that the basalt outcropping on the beach (the base of which was not exposed in any coastal section) occurs as a more or less horizontal sheet. The thickness of the basalt, as disclosed by the boring operations, proved to be very variable, owing probably to the erosion it appears to have undergone. The basalt met with at no great depth below the ground level, in five of the boreholes, was found to vary in thickness from 31 to 97 feet, and the water-bearing rocks underlying it showed no hardening or other signs of contact alteration. The bores put down in close proximity to Stirling street, which runs generally east and west from the coast to the mouth of Meredith Creek at its junction with the entrance to Leschenault Inlet, failed to reach the basalt disclosed in the northern group of boreholes. The deepest, Meredith Creek bore (or bore No. 3 as described in the Annual Report of the Geological Survey for 1897), was carried down to a depth of 416 feet, through alternating beds of clay (? shales), incoherent sandstone and conglomerate. This absence of basalt

suggests that the columnar basalt exposed on the coast and in the Brewery and other bores to the north of Stirling street is merely a remnant of a much larger sheet which spread over a somewhat larger area. This sheet possibly extended to the eastward and formed part of the patches in the Preston River valley described by Mr. Hardman, and indicates that the basalt was poured out on the surface as a lava flow, rather than being of an intrusive character.

Mr. A. Montgomery, in the account (p. 97) of his investigations in connection with the prospects of discovering petroleum in the Warren River district during 1903 on the south coast, pointed out that the sedimentary beds exposed in the rocky outcrop to the west of Black Point exhibited a twisted and crumpled stratification, due in all probability to the intrusion of a sheet of basalt between the bedding planes. On the other hand, the basalt met with in the Western Mining and Oil Corporation No. 1 bore on the Warren River was somewhat scoriaceous and represented a lava flow of a similar lithological character to that at Silver Mount.

Whether the igneous activity to which reference has been made, synchronised with that of the period of the deposition of the strata exposed in the Wilga-Collie-Donnybrook area, or represented a different stage in the geological history of the formation, does not yet appear to have been definitely established. It is, however, perfectly clear that no basaltic lava flows occur anywhere along the eastern margin of the area from Collie to the Warren River.

CORRELATION.

Consideration of the correlation of the Donnybrook Sandstone Formation with those of other regions in which the stratigraphical column has been standardised, may be approached from two distinct angles, viz., (a) that of correlation between different provinces in the same continent, and (b) that of long distant correlation between continents. These considerations differ somewhat for the two cases enumerated, for geological correlation is not only important as an end in itself, but also as a stepping stone to other things, and has in addition economic applications. Faunal and floral identity, together with the relationship to tectonic and other allied geological evidence, each have their place in endeavours to solve the problem.

An extensive search was made during the field investigations carried out in the south-west district during 1911, for any palaeontological evidence with which to assist at arriving at the position of the series in the stratigraphical column. Owing to the configuration of the country, much of the area being covered with a mantle of superficial deposits, and few natural sections visible, rendered the search for fossils difficult, and with the single exception of a very imperfect mollusc (?) from the sandstone in the Government Quarry about three miles to the north of Donnybrook, none were found. In the year 1938, however, Dr. Curt Teichert, the research palaeontologist in the University of Western Australia, discovered fossil footprints of an unidentified quadruped about the size of a dog in a sandstone from the Donnybrook district. The conditions under which the Donnybrook beds were laid down, being such as would enable vertebrates to move about freely, thus render it probable that more intensive search than has hitherto been found possible will result in further discoveries.

Consideration of the problem of endeavouring to ascertain whether a geological synchronism of the Donnybrook Sandstone Formation can be established between it and others in the Australian continent, several outstanding facts are available. It is unnecessary to give in detail a general account of such formations, for they are well known and have been fully described by other observers; attention will, therefore, only be directed to their salient stratigraphical, tectonic and other significant features.

Australia.—A considerable development of sandstones, grits, shales and thin beds of conglomerate, of freshwater or estuarine origin occurs in New South Wales, and is referred to as the Hawkesbury Series. In no other part of the mainland of Australia is this formation so widely spread as in New South Wales. Such observations as have been made on it, together with the completeness and variety of the series, its petrographical constitution, as well as its fossil fauna and flora, give it considerable importance in comparative geology. The formation is also of considerable thickness, for the base of the series in the neighbourhood of Sydney is nearly 3,000 feet below sea level. The Hawkesbury Series has been intruded by basalt (dolerite) dykes, though no evidence of surface lava flows appears to have been recorded. The available palaeontological evidence indicates a Triassic Age for the series. The Donnybrook Sandstone Formation bears a close resemblance to the Hawkesbury Series, of which it may be the equivalent. Small quantities of gold occur in some of the sandstones of the Hawkesbury Series, and it is probably more than a coincidence that gold of secondary origin has been recorded by Messrs. Blatchford and Forman in one of the sandy beds of the Donnybrook Sandstone Formation. In this connection it may be pointed out that some types of mineral deposits appear to be connected with igneous activity, which either supplied the heat and vapours, or set auriferous solutions in circulation.

A formation which in many important respects resembles that of the Hawkesbury Series of New South Wales, of which it is believed to be of the same geological age, covers a fairly extensive area in the central, south-eastern and eastern districts of the island of Tasmania. The strata estimated to be over 1,200 feet thick, and of freshwater or estuarine origin, consist largely of sandstones, associated with coal seams, the most important in the State. The beds contain a fossil flora which clearly link them with the Hawkesbury Series; in addition, a single bone of a fossil reptile, stated to belong to the order Cotylosauria, has been recorded from the rocks near Hobart, indicating a lower Triassic Age for the formation. The strata of this age in Tasmania are marked by the intrusion of dolerites, in the form of laccolites, sills sometimes 2,000 feet thick, and dykes to an extent which differentiates them from equivalent strata on the mainland. These evidences of vulcanicity marked the close of the Triassic Period in Tasmania. These intrusions were associated with such earth movements as gave this geological era in Tasmania several features of individuality. The doleritic intrusions which intersect the Tasmanian Coal Measures find their analogue in the Karoo beds of South Africa, where evidences of a stupendous outburst of vulcanic energy are so pronounced. The tabulated analysis of the Karoo dolerites by E. Cohen bear a resemblance to those from south-western division of Western Australia by Dr. Edwards. Their congenetic nature is indicated by general similarity in chemical and mineralogical composition, and implies that they form part of a single petrographical province.

An assemblage of lacustrine strata, at least 2,000 feet thick, containing low-grade coal seams, has been met with in South Australia, at Leigh's Creek, to the eastward of Lake Torrens. These beds, which are stated to lie in a faulted basin, bounded by rocks of Lower Palaeozoic Age, in many respects bear a marked stratigraphical resemblance to those at present under discussion. The Leigh's Creek beds have, on the available palaeontological evidence, been assigned to the Lower Mesozoic (Triassic) Period. There are other areas in South Australia in which strata, inferentially of the same age, have been met with in the course of boring operations, thus indicating a fairly wide extension of this formation.

SOUTH AFRICA.—The marked stratigraphical and tectonic parallelism between Western Australia and that of South Africa, and the other countries bordering the southern portion of the Indian Ocean, has often been made the subject of scientific remark. It is significant to note that the fossil remains of a carrion-eating reptile—*Gomphognathus*—about the size of a large dog, has been found in the upper portion of the Beaufort (Triassic?) Beds, which were originally named the "Republican Beds." This, however, while suggestive, can hardly be taken as definite evidence that the deposits in the two continents are of equivalent age. The Beaufort Beds bear a marked stratigraphical resemblance to the strata occurring in the extreme south-western division of this State. The Beaufort Beds of South Africa contain, in addition to the fossil vertebrates, by which the series is characterised, representatives of the Glossopteris flora, examples of which have been met with in the strata of the Collie Coalfield in Western Australia. The Donnybrook Sandstone Series is non-marine in origin, and there appear to be sound geological reasons for regarding it as representing some portion of the Karoo system as typically developed in and extending over such a large area of South Africa, and the equivalent Gondwana system of India. However, until further fossils are discovered in Western Australia, confirmation of this view must remain somewhat a matter of conjecture. The environment under which the beds were deposited is not only of considerable scientific interest, but has important economic applications by virtue of the occurrence of coal seams, as well as its hydrological aspects. The Karoo System, a widespread formation of continental origin, forms a laterite capped peneplain, now undergoing dissection, contains what is practically an unbroken chain of vertebrate life, ranging from Middle Permian to the close of Triassic time, and the land plants, as well as coal seams, of the Mesozoic Continent of Gondwanaland.

There are scientific reasons for believing that what is now Western Australia formed a remote corner of this ancient continent which linked Africa—structurally the most stable of all the continents—and the countries bordering the Indian Ocean, *i.e.*, Madagascar, India, etc.

A great revolution in physical geography resulted in the dismemberment of Gondwanaland, and produced, *inter alia*, the present continent of Australia, by virtue of what has generally been described as the Wegener Drift hypothesis. This is based on the assumption that the continents are merely broken fragments of a great sheet of lighter and more acid rock floating upon a denser one of more basic composition. This, however, does not necessarily imply that the present shore lines were absolutely adjacent, but that they were very much closer at different periods of geological history, and have always maintained a more or less general parallelism. The con-

ception also implies that these fragments may still be wandering laterally: that such is the case may be inferred from the results of a comparison of the determinations of longitude made between the years 1823, 1870, and 1932, from which it was shown that Sabine Island, in East Greenland, had moved some considerable distance to the westward. Recent researches, however, indicate that such lateral wandering could also have resulted from a differential vertical and subsidence of crustal blocks, due to a shrinking of the earth's crust. The exact explanation of this continental wandering is not yet quite clear, though it may, as the matter becomes more closely investigated, be found to have resulted from a combination of both factors. However this may be, enquiry into the causes of such peregrinations is foreign to the scope of this paper. On the lines of Wegener's speculations and collateral results, it is to the westward that those great connections which help to explain the many problems of the past and present geological history of Western Australia will have to be looked for.

In view of the marked structural, stratigraphical and palaeontological resemblance of the western portion of the Australian continent, to that of India, South Africa, and Madagascar, as exhibited in all the formations from the Archaean to the Recent epoch, it is important to consider the bearings which such have upon the matter of the intercontinental relationships of the Donnybrook Sandstone Formation.

A careful study of the latest geological maps of South Africa, India and Australia is of special value in any endeavour to reassemble the broken fragments of Gondwanaland, which in view of its wanderings must originally have had a very much smaller area than has been usually pictured. Attempts have been made by some to replace the Australian continent in the position it inferentially occupied in relation to the stable mass of Africa, by the suggestion that Australia and New Guinea, along with its island satellites, had drifted away to the eastward from what is now the Arabian Sea. This view, however, on account of the dissimilarity of the geological constitution and grain of the countries bordering the Arabian Sea, hardly seems feasible. Another view of this reconstruction inclines to the belief that the eastern coastline of Madagascar, which has a general parallelism to that of the South African coast, was in intimate connection with Peninsular India on its western flank. If as part of this suggested continental union, Australia originally occupied a portion to the southward of Madagascar, it would furnish an explanation of the marked concordance not only in the geological structure but also the grain and other stratigraphical characteristics. A feature of some significance in this connection is the dominant east-west strike of the trend lines of the folding exhibited in the older rocks of the southern corner of Africa, and that represented by the Stirling Range-Mount Barren beds. Of these the eastern extension probably lies beneath the Great Australian Bight in close association with the depression, the Jeffrey Deep of the Admiralty Charts and thence through Kangaroo Island to Eyre's Peninsula in South Australia.

SUMMARY.

Whenever an answer to the question as to the precise geological age of the Donnybrook Sandstone Formation is received, it will, in probability, be found to have resulted from a combination of palaeontological and other recognised stratigraphical researches. As its name suggests, this group, which

covers a wide extent of country in the south-west corner of the State, consists chiefly of sandstones, alternating with shales and coal seams of workable thickness, together with thin layers of more or less impure limestones. Regional block-faulting has affected the formation, and has been responsible for the preservation of the mineral wealth in its coal measures, the annual production of which, furnished the entire coal output of Western Australia. In intimate association with these beds is a large development of basaltic rocks of the precise age of which there is at present no direct geological evidence. The base of the Donnybrook Sandstone Formation has not been seen, though it has been met with in the course of boring operations at depths which vary from 500 to 1,130 feet from the surface. Few fossils, the guiding stars of sedimentary geologists, have been met with in this strata, whilst the number of identifiable plant remains hitherto recorded from the formation is comparatively small, and appears to be insufficient to warrant discussion of its relationship to the faunas elsewhere. In the absence therefore of detailed palaeontological evidence, determination of the geological age of the formation is mainly dependent upon a correlation of petrological characters, structural peculiarities, community of origin, tectonic relationships, and the results of other cognate activities.

Whenever the obscurities which at present envelope the problem are considered it seems quite clear that further sympathetic co-operation, both in the field, the study, and the laboratory will be required to establish beyond doubt the geological epoch to which the Donnybrook Sandstone Formation and its associates belong.

CONCLUSION.

After giving due weight to all the considerations involved, it would seem that evidence for a Triassic Age of the Donnybrook Sandstone and its associates can be discerned. Such has, with a measure of confidence in striking contrast to the, as yet circumstantial data, strong claims to acceptance as a working hypothesis, bearing clearly in mind that "Pioneer Geology has to choose between the rashness of using imperfect evidence, or the sterility of uncorrelated and unexplained facts."

BIBLIOGRAPHY.

BEYSCHLAG, F., and KRUSCH, P.: "Die Goldgänge von Donnybrook in West Australien." *Zeitschr. für Prakt. Geol.*, Berlin, 1900, pp. 169-174.

BLATCHFORD, T.: "Gold Discoveries at Donnybrook." *Ann. Prog. Rep. Geol. Sur. W.A. for* 1898, pp. 50-51.

———— "On the Development of Mining in the Locality of Donnybrook." *Ann. Prog. Rep. Geol. Sur. W.A. for* 1899, pp. 34-35.

———— "On the Discovery of Coal 5½ miles north-east of Wilga Siding on the Donnybrook-Katanning Railway." *Ann. Prog. Rep. Geol. Sur. W.A. for* 1918, pp. 73-74.

———— "Boring for Coal in the Vicinity of Nannup." *Ann. Prog. Rep. Geol. Sur. W.A. for* 1929, pp. 10-12.

BROWN, H. Y. LYELL: "Geological Report on Country in the Neighbourhood of Staunton Springs, Williams and Canning Rivers, Bunbury and Cape Leeuwin." Perth, 1872.

———— "General Report on a Geological Exploration of that portion of the Colony of Western Australia lying southward of the Murchison River and westward of Esperance Bay." Perth, 1873.

CAMPBELL, W. D.: "Capel Water Supply." *Ann. Prog. Rep. Geol. Sur. W.A. for* 1909, p. 15.

CHAPMAN, F.: "Notes on Fossils from the Collie Coalfield in the Collection of the National Museum, Melbourne." *Geol. Sur. W.A., Bull.* 27, 1907, pp. 9-18.

CLARKE, E. de C., and WOODWARD, H. P.: "Reported Occurrence of Oil near Wonnerup, South-West Division." *Geol. Sur. W.A., Bull.* 74, 1917, pp. 65-74.

DAVID, T. W. E., and ETHERIDGE, R., junr.: "On the mode of attachment of the leaves or fronds to the caudex in Glossopteris, etc. With a note on its stratigraphical distribution in Australasia." *Proc. Linn. Soc. N.S.W., Ser. ii., Vol. ix.*, 1894, p. 288.

EDWARDS, A. B.: "Tholeiite Basalts from Cape Gosselin, Western Australia." *Jour. Roy. Soc. W.A., Vol. xxii.*, 1936, pp. 19-23.

———: "Tertiary Tholeiite Magma in Western Australia." *Jour. Roy. Soc. W.A., Vol. xxiv.*, 1938, pp. 1-12.

EMELGANOO, A.: "Le gisement d'Or de Donnybrook, Australie Occidentale Vést Zolotopromysle, Tomsk, Siberia," 1901, pp. 149-151. (Messager de l'industrie auriferé et des Mines en générale.)

ETHERIDGE, R., junr.: "Plant Remains from the Collie Coalfield." *Geol. Sur. W.A., Bull.* 27, 1907, pp. 7-8.

———: *Vide* David, T. W. E.

FORMAN, F. G.: "Inspection of Gold Prospecting at Donnybrook." *Ann. Prog. Rept. Geol. Sur. W.A. for* 1935, 1936, p. 4.

GLAUERT, L.: "Western Australian Fossil Plants." *Geol. Sur. W.A., Bull.* 36, 1910, pp. 107-110.

GREGORY, F. T.: "On the Geology of a part of Western Australia." *Quart. Jour. Geol. Soc.*, 1861, Vol. xvi., pp. 475-483.

HARDMAN, E. T.: "Report on the Geology and supposed Gold-bearing Rocks in the neighbourhood of Bunbury, Blackwood, etc." Perth: By Authority, 1884.

JACK, R. LOGAN: "Report of the Royal Commission on the Collie Coalfield." Perth: By Authority, 1905, pp. 6-8.

JUTSON, J. T.: "The Physiography (Geomorphology) of Western Australia." *Geol. Sur. W.A., Bull.* 95, 1934, pp. 85-88, 278, 284, 326.

KRUSCH, P.: *Vide* Beyschlag, F.

MAITLAND, A. GIBB: "The Collie Coalfield." *Ann. Prog. Rept. Geol. Sur. W.A. for* 1898, 1899, pp. 13-21.

———: "The Reputed Petroliferous Deposits of the Warren and Donnelly Rivers." *Ann. Prog. Rept. Geol. Sur.*, 1902, pp. 13-15.

———: "The Reputed Petroliferous Deposits of the Warren and Donnelly Rivers." *Ann. Prog. Rept. Geol. Sur. W.A.*, 1904, p. 19.

———: "The Geology of Princess Royal Harbour (Albany), with reference to the occurrence of Oil." *Geol. Sur. Bull.* 26, pp. 27-33.

———: "Recent Advances in the Knowledge of the Geology of Western Australia." *Austr. Assoc. Adv. Sci.*, 1907, Vol. xi., pp. 149-151.

———: "Coal on Prospecting Area 155H, Donnybrook." *Ann. Prog. Rept. Geol. Sur. W.A.*, 1909, pp. 11-13.

———: "The Artesian Water Resources of Western Australia (Cookernup Bore, South-West Division)." *Rept. of the Interstate Conference on Artesian Water*, 1912, Sydney, pp. 119-120.

———: "Boring at Collie." *Ann. Prog. Rept. Geol. Sur. W.A.*, 1920, pp. 9-10.

——————— "Petroleum Prospects of the Busselton Neighbourhood South-West Division." *Ann. Prog. Rept. Geol. Sur. W.A.*, 1920, pp. 6-8.

MONTGOMERY, A.: "Report on the Wilga Coalfield, giving a summary of the results obtained in proving the coal." Perth: By Authority, 1924.

——————— On the Prospects of Discovering Petroleum by Boring in the Warren River District. Appendix I., Div. II. *Ann. Rept. Dept. of Mines for* 1903, *Perth*: By Authority, 1904, pp. 95-98.

PITTMAN, E. F.: "Notes on the Geology and Mineral Deposits of Portions of Western Australia." *Ann. Rept. Dept. of Mines and Agriculture, N.S.W.*, 1897, pp. 136-143. Also *Rec. Geol. Sur. N.S.W.*, Vol. vi., pt. I., pp. 1-17.

SAINT SMITH, E. C.: "A Geological Reconnaissance of a Portion of the South-West Division of Western Australia." *Geol. Sur. W.A. Bull.* 44, 1912.

SIMPSON, E. S.: "The Chemical and Physical Properties of Some of the Donnybrook Sandstones." *Geol. Sur. W.A. Bull.* 74, pp. 75-93.

WILSON, R. C.: "The Wilga Coalfield." *Ann. Prog. Rept. Geol. Sur. W.A.*, 1921, pp. 30-37.

——————— "Report on the Wilga Coal Field" (continued from *Ann. Rept. Geol. Surv.*, 1921). Div. II., *Ann. Rept. Dept. of Mines, W.A.*, 1923, Appendix 14, pp. 70-73.

WOODWARD, H. P.: "The Country Between Perth and Bunbury, Vasse and Fly Brook." *Ann. Gen. Rept. for the Year* 1888-89, *W.A.*," pp. 45-48.

——————— "The Collie River Coal." *Ann. Gen. Rept for the Year* 1890, *W. Aust.*," pp. 38-41.

——————— "Report on the Collie Coal Field, together with reports by Dr. J. R. M. Robertson, W. B. Pendleton, and W. T. Atkinson," Perth: By Authority, 1894.

——————— "Notes on the Geology of Western Australia." *Geol. Mag.*, 1894, i. (4), p. 548.

——————— *Annual Report for* 1894 ((a) "The South-Western Portion of the Colony"; (b) "The Collie Coalfield"). Appendix 1 and 2, *Rept. of the Dept. of Mines, W.A., for the Year* 1894, 1895, pp. 8 *et seq.*

——————— "Prospecting for Coal at Collie." *Ann. Prog. Rept. Geol. Sur. W.A.*, 1908, p. 6.

——————— "The Geology and Mineral and Allied Resources of the South-West Division." *Ann. Prog. Rept. Geol. Sur. W.A.*, 1914, pp. 15-18.

——————— "The Coal Resources of Western Australia." *Geol. Surv. W.A., Bull.* 64, 1915, pp. 7-12.

——————— "The Reputed Petroliferous Area of the Warren River District (South-West Division)." *Geol. Sur. W.A., Bull.* 65, 1915.

——————— "Notes on a Portion of the South-West Division." *Ann. Prog. Rept. Geol. Sur. W.A.*, 1916, pp. 10-11.

———————: *Vide* Clarke, E. de C.

WOOLNOUGH, W. G.: "Report of the Royal Commission on the Collie Coal Industry." Perth: By Authority, 1916, pp. v.-x.